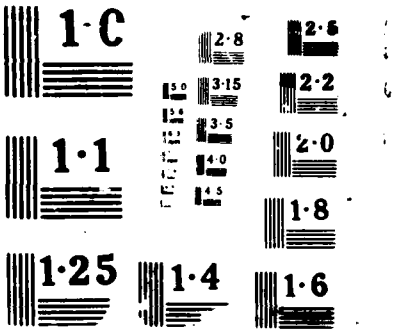
AD-A188 014 QUANTUM LIMITS OF SUPERCONDUCTING HETERODYNE RECEIVERS 1/1
(U) CALIFORNIA UNIV BERKELEY DEPT OF PHYSICS
P L RICHARDS 07 OCT 87 AFOSR-TR-87-1692 AFOSR-85-0238
UNCLASSIFIED F/G 9/1 NL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DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

AD-A188 014

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION

3. DISTRIBUTION/AVAILABILITY OF REPORT

Unlimited

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE

4. PERFORMING ORGANIZATION REPORT NUMBER(S)

5. MONITORING ORGANIZATION REPORT NUMBER(S)

AFOSR-TR- 87-1692

6a. NAME OF PERFORMING ORGANIZATION
The Regents of the University of California

6b. OFFICE SYMBOL (If applicable)

7a. NAME OF MONITORING ORGANIZATION
AFOSR,

6c. ADDRESS (City, State, and ZIP Code)
Sponsored Projects Office
Berkeley, California 94720

7b. ADDRESS (City, State, and ZIP Code)
Building 410
Bolling Air Force Base
Washington, D.C. 20332-6448

8a. NAME OF FUNDING/SPONSORING ORGANIZATION
AFOSR/NE

8b. OFFICE SYMBOL (If applicable)
NE

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
AFOSR ~~Grant~~ #85-0230

8c. ADDRESS (City, State, and ZIP Code)
Building 410
Bolling Air Force Base
Washington, D.C. 20332-6448

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO	WORK UNIT ACCESSION NO.
61102F	2305	C3	

11. TITLE (Include Security Classification)
Annual Technical Report

12. PERSONAL AUTHOR(S)
Richards, Paul L.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Annual	FROM 5/15/86 TO 5/14/87	1987 October 7	4

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Not required.

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20. DISTRIBUTION/AVAILABILITY OF ABSTRACT
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION

22a. NAME OF RESPONSIBLE INDIVIDUAL
Weinstock

22b. TELEPHONE (Include Area Code)
(202) 767-4933

22c. OFFICE SYMBOL
NE

DD Form 1473, JUN 86 Previous editions are obsolete SECURITY CLASSIFICATION

AFOSR-TR- 87-1692

ANNUAL TECHNICAL REPORT TO THE

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

Grant No. USAF-AFOSR-85-0230

"Quantum Limits of Superconducting Heterodyne Receivers"

Period: May 15, 1986 - May 14, 1987

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Summary

The goal of this research is to produce quantum limited SIS quasiparticle heterodyne receivers at submillimeter wavelengths. The approach is to compare the performance of waveguide and planar lithographed quasi-optical SIS mixers in W-band (λ~3mm) in order to understand the factors which degrade the performance of the latter. This information will be used to optimize the planar quasi-optical mixers. Finally, these optimized designs will be scaled to submillimeter wavelengths. Systematic tests of both types of mixers have been carried out during the second grant year. Improved designs of planar quasi-optical mixers have been designed and fabricated. The construction of test apparatus for submillimeter wavelengths has begun.

Statement of Work

Tests have been carried out on a W-band waveguide mixer block which can be tuned from 2.7 - 3.7mm (80-100 GHz) with a single mechanical adjustment. This mixer has an instantaneous bandwidth of ~3GHz and uses an IF transformer with high input impedance

(500 - 700Ω). When used with 2x2$(\mu m)^2$ Pb-based junctions from NBS Boulder this mixer gave a DSB gain of 8-12 dB, which is the highest ever seen in an SIS mixer. It also gave mixer noise temperatures of T_m (DSB) of 6-15K, which are the lowest yet observed at these frequencies. Preparations have been made to test Ta - based junctions from Yale in this mixer block. These should give significantly lower mixer noise.

A new quasi-optical test apparatus has been used to evaluate several types of planar lithographed mixer with bow-tie antennas. The integrated structures were fabricated at NBS Boulder using Pb-based and Nb-based junction technologies. They included mixers made with a single junction, a single junction tuned with a microstrip stub, series arrays of 5 junctions, and series arrays of 5 junctions tuned with a parallel wire inductor. In all cases the measured coupling coefficient and the bandwidth agreed well with calculations based on simple equivalent circuits models and on the nominal parameters of the structures. Measurements were made of mixer gain and noise and comparisons were made to the performance of waveguide mixers with similar types of junction. These comparisons indicate that there is a 6-7 dB loss between the cryostat window and the terminals of the bow-tie antenna. When corrected for this loss, the gains of the bow-tie mixers were comparable to the waveguide mixers, but the noises were higher by factors of 3-6. Preparations are being made for improvements in the optical system and for the use of log-periodic antennas to reduce the antenna loss. The reasons for the excess noise are being investigated.

Publications

W. R. McGrath, A. V. Räisänen, and P. L. Richards, Variable-Temperature Loads for Use in Accurate Noise Measurements of Cryogenically-Cooled Microwave Amplifiers and Mixers, Int. J. Infrared and Millimeter Waves 7, 543 (1986).

D. W. Face, D. E. Prober, W. R. McGrath, and P. L. Richards, High Quality Tantalum Superconducting Tunnel Junctions for Microwave Mixing in the Quantum Limit, Applied Phys. Lett. 48, 1093 (1986).

D. G. Crété, W. R. McGrath, P. L. Richards, and F. L. Lloyd, Performance of Arrays of SIS Junctions in Heterodyne Mixers, IEEE Trans. Microwave Theory Tech. MTT-35, 435 (1987).

P. L. Richards, D. G. Crété, Li Xizhi, W. R. McGrath, D. W. Face, D. Prober, and F. L. Lloyd, Advances in SIS Quasiparticle Mixers, 1986 Applied Superconductivity Conference Abstract, IEEE Trans. Magn. (to be published).

A. V. Räisänen, D. G. Crété, P. L. Richards, and F. L. Lloyd, Low Noise SIS Mixer with Gain for 80-115 GHz, European Space Agency Workshop Proc. ESA SP-280, 255 (1986).

A. V. Räisänen, D. G. Crété, P. L. Richards, and F. L. Lloyd, Wide-Band Ultra Low Noise mm-Wave Mixers with a Single Tuning Element, 16th European Microwave Conf. Proc. p. 252 (1986).

W. R. McGrath, P. L. Richards, D. W. Face, D. E. Prober, and F. L. Lloyd, Performance of mm-Wave SIS Mixers Employing Pb-Alloy and Ta/PbBi Tunnel Junctions, (to be published).

A. V. Räisänen, D. G. Crété, P. L. Richards, and F. L. Lloyd, Wide-Band, Low Noise MM-Wave SIS Mixers with a Single Tuning Element, Int. J. Infrared and Millimeter Waves 7(12), 1835 (1986).

A. V. Räisänen, D. G. Crété, P. L. Richards, and F. L. Lloyd, A 100 GHz SIS Quasiparticle Mixer with 10 dB Coupled Gain, IEEE MTT-S Digest, 929 (1987).

D. W. Face, W. R. McGrath, P. L. Richards, and D. E. Prober, Accurate Experimental and Theoretical Comparison Between Superconducting Mixers Showing Strong and Weak Quantum Effects, ISEC'87 Conf. Proc. (to be published).

Personnel Associated with the Effort

D. G. Crété, Visitor
A. V. Räisänen, Visitor
P. L. Richards, Professor
Q. Hu, Postgraduate Research Physicist
C. Mears, Graduate Student Research Assistant

Interactions, Coupling Activities

Invited Talks

P. L. Richards, Progress in the Development of SIS Quasiparticle Mixers, Applied Superconductivity Conference, Baltimore, Maryland, 9/28 - 10/3/86.

P. L. Richards, Superconductive Mixers, Air Force Applications of Cryoelectronics, Dayton, Ohio, October 30, 1986.

P. L. Richards, SIS Quasiparticle Mixers, Joint Services Electronics Programs Review, Berkeley, November 5, 1986.

P. L. Richards, RF Impedance Matching Structures for Planar SIS Mixers, Submillimeter (Terahertz) Receiver Technology Conference, Lake Arrowhead, Calif., April 7-8, 1987.

P. L. Richards, Superconducting Detectors, Seminar at Santa Barbara Research Center, Goleta, Calif., May 28, 1987.

Contributed Talks

A. V. Räisänen, D. G. Crété P. L. Richards, and F. L. Lloyd, Wide-Band Ultra Low Noise mm-Wave Mixers with a Single Tuning Element, 16th European Microwave Conference, Dublin, Ireland, 8-12 September 1986.

G.-J. Cui, D. W. Face, E. K. Track, D. E. Prober, A. V. Räisänen, D. G. Crété, and P. L. Richards, High Quality Ta/PbBi Tunnel Junctions for 85-110 GHz SIS Mixer Experiments, Applied Superconductivity conference, Baltimore, Maryland, 9/28-10/3/86.

D. G. Crété, A. V. Räisänen, W. R. McGrath, P. L. Richards, and F. L. Lloyd, Low-Noise 80-115 GHz SIS Mixers with a Single Tuning Element, 11th Int. Conf. on Infrared and mm-waves, Pisa, Italy, 20-24 October 1986.

W. R. McGrath, P. L. Richards, D. W. Face, D. E. Prober, and F. L. Lloyd, Performance of mm-Wave SIS Mixers Employing Pb-Alloy and Ta/PbBi Tunnel Junctions, Pisa, Italy, 20-24 October 1986.

A. V. Räisänen, D. G. Crété, P. L. Richards, and F. L. Lloyd, A 100 GHz SIS Quasiparticle Mixer with 10 dB Coupled Gain, 1987 IEEE International Microwave Symposium, Las Vegas, Nevada, June 9-11, 1987.

Statement

There have been no inventions or patents disclosures during this grant year.

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